

Preliminary Planning for NEAR's Low-Altitude Operations at 433 Eros

P. G. Antreasian,[†] C. L. Helfrich, J. K. Miller, W. M. Owen, B. G. Williams, D. K. Yeomans,

Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Dr., Pasadena, CA 91109

D. J. Scheeres

Dept. of Aerospace Engineering and Engineering Mechanics, Iowa State University,
Ames, IA 50011

D. W. Dunham, R. W. Farquhar, J. V. McAdams, A.G Santo, G.L. Heyler

The Johns Hopkins University, Applied Physics Laboratory,
Johns Hopkins Road, Laurel, MD 20723

EXTENDED ABSTRACT

On February 14, 2000, an orbit insertion burn will place NASA's Near Earth Asteroid Rendezvous (NEAR) spacecraft (S/C) into orbit around asteroid 433 Eros. NEAR will initially orbit Eros with distances ranging from 500 to 100 km in order to characterize the shape, gravity and spin of Eros. Once the physical parameters of Eros are determined reasonably well, the plan is to establish an orbit of the NEAR S/C with increasingly lower altitudes as the one year orbital mission progresses while further characterizing the gravity and shape of Eros. Towards the end of the NEAR mission, after the shape, gravity and spin of Eros have been well characterized, the scientific interest of obtaining very close observations (< 5 km) can be realized. The navigation during this phase relies on a combination of NASA's Deep Space Network (DSN) radio metric tracking, laser ranging (LIDAR) data from the S/C to the surface of Eros, and onboard optical imaging of landmarks on Eros. This paper will provide preliminary plans for mission design and navigation during the last two months of the orbit phase, where several close passes to the surface will be incorporated to enhance the science return. The culmination of these close passes will result in the eventual landing of the S/C on the surface of Eros. Several considerations for these plans are given by *Antreasian, et al.* [1998]. The objective for the end of the mission will be to land the S/C autonomously using the surface relative information obtained from the onboard LIDAR instrument. The goal will be to *soft* land the S/C in such a way as to keep it operational. With the use of an onboard LIDAR landing algorithm as discussed by *Antreasian et al.* [1998], it is believed that the S/C impact velocity can be kept well under 7 m/s which is a requirement for allowing the S/C to remain operational.

A recent aborted rendezvous maneuver upon approach to Eros caused a delay in the original Eros orbital phase of NEAR's mission. Instead of achieving the necessary Eros relative velocity which was required for orbit insertion, NEAR continued to fly within 3828 km past the asteroid on December 23, 1998. A large maneuver (932 m/s) was then executed on January 3rd, 1999 to reduce the asteroid relative velocity and return it back for a rendezvous with Eros in February of 2000. Despite the year delay to the main objective of NEAR's mission, the recent flyby of Eros provided important preliminary navigational information for the orbit phase. Preliminary estimates for the physical parameters of Eros, such as shape, mass, spin axis and rotation rate have been determined [*Miller et al.*, 1999]. The effects of these parameters will be incorporated into the design of the close flyby and landing trajectories. The images of Eros that were obtained during the flyby show interesting features on the surface of Eros. One interesting feature is a large crater near the long end of Eros's equatorial region. The feasibility of observing this and other features at close range will be discussed.

At close altitudes, the strong perturbations from the irregular gravity field of Eros cause large changes to orbit energy and eccentricity. These effects can lead to unstable situations where the S/C is suddenly placed on either an escape or impact trajectory. By defining an averaged potential for the ellipticity effect from the gravity harmonic, C_{22} , on the S/C orbit, *Scheeres et al.* derives the basic form of equations for the changes in energy and angular momentum during one orbit. With the consideration of the variation of these parameters for orbit design, two feasible approaches

[†] Jet Propulsion Laboratory, 4800 Oak Grove Dr., M/S 301-276, Pasadena, CA 91109-8099
Phone: (818) 354-4381
Email: pga@pop.jpl.nasa.gov
FAX: (818) 393-5214

have been analyzed by Antreasian *et al.* [1998] to effect low altitude flybys of the Eros surface, enabling high-resolution imagery and localized gravitational measurements. These include: (1) tight retrograde orbits which have the drawback of high relative velocity with the surface, and (2) targeted low passes to some latitude and longitude which have the possibility of smaller relative velocity with the surface. Figure 1 shows an example of a tight retrograde orbit (25 km radius, 170° inclination) that is currently being planned for close observations. Note that the asteroid rotates in the right-hand sense about the Eros-fixed z-axis which describes the instantaneous rotational pole in this frame, while the S/C moves around the asteroid in the opposite (retrograde) direction.

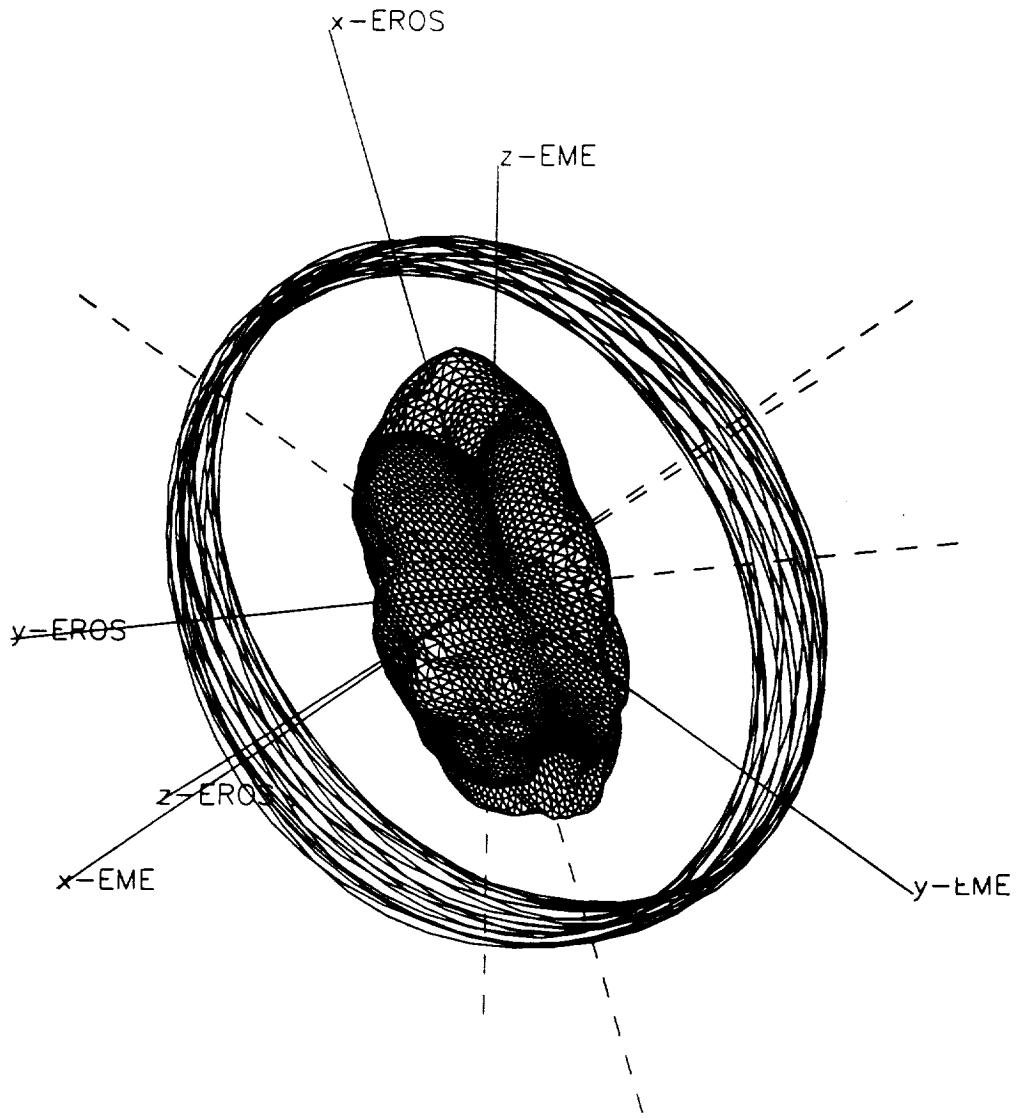


Figure 1: Oblique view of the 25 km orbit in the Eros-Mean-Equator inertial frame.

The close passes described above will culminate with a landing of NEAR on the surface of Eros which will mark the end of the mission. The navigation challenge is to be able to execute the final maneuver as late as possible, as this will minimize the impact speed. The measurements available to the S/C during this time are its *a priori* solution prior to the de-orbit maneuver, the ACS which maintains the S/C attitude during the entire trajectory, and the accelerometers which are used to control the pre-planned maneuvers. To push the impact speed to an appreciably lower value, such as under 1 m/s, requires the inclusion of altimetry data into the navigation design. The simplest approach would have the S/C make altimetry measurements using the LIDAR after the initial descent has commenced. The S/C would compare these measurements to the nominal descent profile and use the offset between

them to shift the execution time of all subsequent maneuvers. The implementation of this autonomous control would consist of comparing altitude measurements and their measurement epochs with the nominal profile and shifting the final time by the corresponding amount.

Pointing constraints peculiar to the NEAR S/C for solar array point, science pointing and telecommunications and tracking will be addressed in the paper. Requirements for telecom and tracking during the low passes and landing will be developed.

ACKNOWLEDGEMENTS

The research described in this paper was carried out jointly by the Jet Propulsion Laboratory, California Institute of Technology, and the Johns Hopkins University, Applied Physics Laboratory under contract with the National Aeronautics and Space Administration.

REFERENCES

P.G. Antreasian, C.L. Helfrich, J.K. Miller, W.M. Owen, B.G. Williams, D.K. Yeomans, J.D. Giorgini, D.W. Dunham, R.W. Farquhar, J.V. McAdams, D.J. Scheeres, "Preliminary Considerations For NEAR's Low-Altitude Passes And Landing Operations At 433 Eros," *AIAA/AAS Astrodynamics Specialist Conference*, August 10-12, 1998, Boston, MA, Paper AIAA98-4397.

J.K. Miller, W.M. Owen, J.D. Giorgini, R. Gaskell, P.G. Antreasian, B.G. Williams, "Estimation of Eros Physical Parameters for NEAR Orbit Phase Navigation," *AAS/AIAA Astrodynamics Specialist Conference*, Girdwood, AK, August 16-18, 1999, paper submitted.

C.E. Helfrich, J.K. Miller, P.G. Antreasian, E. Carranza, B.G. Williams, D.W. Dunham, R.W. Farquhar, J.V. McAdams, "Near Earth Asteroid Rendezvous (NEAR) Revised Eros Phase Trajectory Design," *AAS/AIAA Astrodynamics Specialist Conference*, Girdwood, AK, August 16-18, 1999, paper submitted.

D.J. Scheeres, F. Marzari, L. Tomasella, V. Vanzani, "ROSETTA mission: satellite orbits around a cometary nucleus", *Planetary and Space Science*, in press.